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A Study of Optimum Blank Shape for Square Cup Drawing Using Finite Element Method

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Abstract

The aim of this study is to determine the optimal blank shape for a square cup drawing with uniform flange (square and circular flange).A new algorithm is proposed to control of flange shape based on shape error. To reduce earing defects on boundary of deformed flange, the initial blank shape was iteratively modified. This modification is repeated until an optimal blank shape for the part is achieved. To apply this algorithm, 3D model of deep drawing was used and analyzed by Ansys 11.0 FEM code.

Low carbon steel was chosen to carryout the simulation. The results show that the shape of optimum blank has significantly reduced the earing defects in few iterations by using this algorithm.

Keywords: optimal blank, square cups, finite element

دراسة لإيجاد أفضل شكل غفل لانتاج قدح مربع باستخدام طريقة العناصر المحددة

الخلاصة

يهدف البحث الى تصميم افضل شكل غفل خلال عملية السحب العميق لإنتاج قدح ذو مقطع مربع بشكل نهائي (ذو فلنجة مربعة ودائرية).تم اقتراح خوارزمية للسيطرة على شكل الفنجة بالإعتماد على الخطأ بالشكل الهندسي. لتقليل التأذن الحاصل خلال العملية، تم تغييرشكل الغفل الأولي بصورة متكررة وإن هذا التغيير يستمر تى نحصل على الشكل المطلوب. تم بناء نموذج ثلاثي الابعاد بأستخدام برنامج Ansys 11.0 . تم اختيار الفولاذ المنخفض الكاربون لأجراء المحاكاة. بينت النتائج إن الخوارزمية المستخدمة ذات كفاءة في تقليل التأذن خلال تكرارات قليلة.

1. Introduction

Traditionally the optimal blank is referred to an initial blank shape to produce a net shape. The net shape means that the trimming process is neglected completely in forming process. In deep drawing, the sheet metal takes the shape of the punch and the die when it is pushed into the die cavity by punch, thus forming a cup. The top edges of a cup formed by deep drawing are not usually even. They are often wavy having crests and valleys. This phenomenon called earing. Earing is undesirable, as it. Requires some metal to be trimmed from the top of the cup. This consumes money and time.

In general, sheet metal forming processes in modern industries deal with complicated shapes and the forming process consists of several attempts until the final shape is formed. The initial blank shape for a part is determined mostly by experimental trial and error method. As a result of rapid progress in computing facilities,

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numerical tools based on the finite element method have become common for design of sheet metal forming components.

in recent year, researchers focus on numerical study because it provides insights on the material behavior during process.

M.H.Parsa et al. [1] studied the effects of die opening shape and drawing depth on the error shape of initial blank by using slip line method to predicting the initial blank shape and force required for deformation of the blank.

Kichan and Hyunbo [2] proposed a new method of optimal blank shape design using the initial nodal velocity for the drawings of arbitrary shaped cups. Initial blank shape has been found from the motion of boundary nodes.

W.Hmmami et al. [3] have presented an approach to determine the optimal blank shape for a rectangular cup based on Push/Pull technique and this technique is applied to two different FEA codes (DD3MP) and (ABAQUS).

R.Padmanabhan [4] presented a numerical study on effect of initial anisotropy in the finite element blank and orientation of the blanks rolling direction during deep drawing process to determine he optimal blank shape for a cup.

The numerical method is based on an initial NURBS surface used to define the blank shape and the resulting flange geometry of deformed part.

H.Sahari et al. [5] have been developed a finite element Formulation based on a combined Total and Updated Lagragian approach to improved the efficiency in the analysis and optimum design of blank of contours of complicated part.

In this paper, a new algorithm used to determine the optimum blank shape design for square cup with uniform flange (square and circular flange) based on shape error. Square blank used as initial blank, it modified in each stage until desired shape is achieved.

2. Optimal blank shape procedure

The proposed algorithm involve two steps, first numerical analysis using finite element and the flange contour of the formed part is compared with the required target contour. Second if the flange contour is different from contour based on location of boundary nodes after drawing. It should be modified the initial blank. A new blank is used as initial for the next stage. The effectiveness of the algorithm is demonstrated with two test problem one with square flange and other with circular flange. The basic idea that used in the modification of a blank is added material to, or subtract from, the current blank. In this paper, the material is added to blank and initial blank is square blank of low carbon steel. In deep drawing process the deformation of blank is nonlinear deformation and that led to move all boundary nodes in unequal distance. The initial blank defined by a group of boundary nodes. The position of each node on boundary of initial flange shape can be expressed by X_i and the position of each node on boundary of final flange shape expressed by x_i.

2.1. Shape error

In order to quantify different between the target shape and the deformed shape, a geometrical measure namely, shape error, expressed by unit of (mm). When the shape error reaches a value less than a predetermined value for a required accuracy in the cup flange. The iterative procedure is stopped because the optimal blank shape for the cup has been obtained. This algorithm is represented in figure (1). After deformation, a final shape of flange is obtain and the compared with desired shape to assurance that the optimum blank shape for the part is achieved. if the shape is different, blank must to be modified. To modify the initial blank it should be found the shape error. Figure (2) shows the proposed algorithm for both square and circular flange.

The shape error of each node can be expressed by:

$$\delta_{xi} = X_{di} - X_i \quad \ldots\ldots(1)$$

The new blank shape calculates as:

$$X_{i\,new} = X_i + \delta_{xi} \quad \ldots(2)$$

X_i : coordinates of each node on boundary of initial blank.

X_{di} : coordinates of each node on boundary of desired blank.

$X_{i\,new}$: coordinates of each node on boundary of modified blank.

The blank shape is iteratively modified until a desired shape is achieved.

In square flange X_{di} constant value and with circular flange $X_{di} = r\cos\alpha$

Where

r: radius of circular flange.

α: angular position of each node on boundary of desired blank.

3. Numerical simulation

3.1. Material

The material used in all simulations is low carbon steel(1008-AISI), where this type is used for stamping applications, such as, automobile bodies engineering application and other applications. To determine the material properties in the sheet, specimen was tested using a tensile test machine type (INSTEN 1195).Table 1 shows the material properties for low carbon steel

3.2. FE Model

For simulating the deep drawing process, FEA software Ansys 11.0 was used 3D 8-node structural solid element of SOLID45 was used for workpiece. The tool set (punch, die and blank holder) was modeled as rigid bodies. Automatic contact procedure in Ansys 11.0 was used to model the complex interaction between the blank and tooling. For rigid (tool set)-flexible (blank) contact 3D 8-node quadrilateral target element of TARGE 170 was used to represent 3D target(toolset) surface which were associated with the deformable body (blank) represented by 3d 8-node contact element of CONTA174. The contact and target surfaces constituted a “contact pair”, which was used to represent contact and sliding between the surface of tool set and workpiece (blank).the coefficient of friction that using in simulation is (0.1). The movement of the punch was defined using a pilot node. Due to the symmetry in the model geometry, constrain and boundary conditions in the horizontal drawing plane. Only one fourth portion of the model needed was be analyzed. The geometry of the tool used in the simulation is shown in Figure (3). The finite element model of the sheet material and drawing die is shown in Figure (4).

4. Results and discussion

The aim of this study is to determine the optimal blank shape for square cup by using new method to find the final contour shape of blank. the proposed algorithm of optimal blank design is found to be very effective in the design of square cup with flange. The described blank shape algorithm procedure capable of determining optimal blank shape for a formed part with few iterations. The initial blank was designed to be square having dimension (70x70x0.5 mm) to obtain the desired cup height of 20 mm. the initial blank was drawn to determine flange contour, then comparing deformed contour to the target contour. The square blank is deformed by deep drawing simulation. in flange cup, the earing defects is occur. Fig. (5) Shows this phenomenon on flange, the maximum value of shape error observed in 0˚and 90˚direction of cup. in this step, the initial should be modified using the proposed algorithm to reducing the earing phenomenon in boundary of deformation cup. to obtained a new initial blank that reduce the earing in next operation. Fig. (6) shows modified blank shape after first drawing. the blank shape is change according to the shape error, which occur during the operation and the modified blank shape use in next iteration. Fig. (7) shows modified blank shape that used to produce square flange and the flange contour after deformation. the result shows some shape errors on flange contour Fig. (8) shows the fourth modification of initial blank that used as optimal blank shape. the deformed shape coincides with the desired contour. Numerical results of cup with circular flange presented in Fig. (9). From result, there is shape error occur in final flange contour and to achieve the desired shape flange contour, the initial blank is modified as shown in Fig. (10) the desired shape flange contour is coincides with the desired contour.

5. Conclusions

The proposed algorithm of optimal blank design based on numerical analysis for square cup is achieved. The algorithm uses an iterative process to find the optimum blank shape. A shape error is used to modify the blank shape that using in next iteration. Optimal blank shape has been presented in this study for both square and circular flange of square cups. The proposed algorithm can be efficient and effective in optimizing blanks in complex stamping. Numerical result showed that the shape of optimum blank has significantly reduced the earing defects.

6. References

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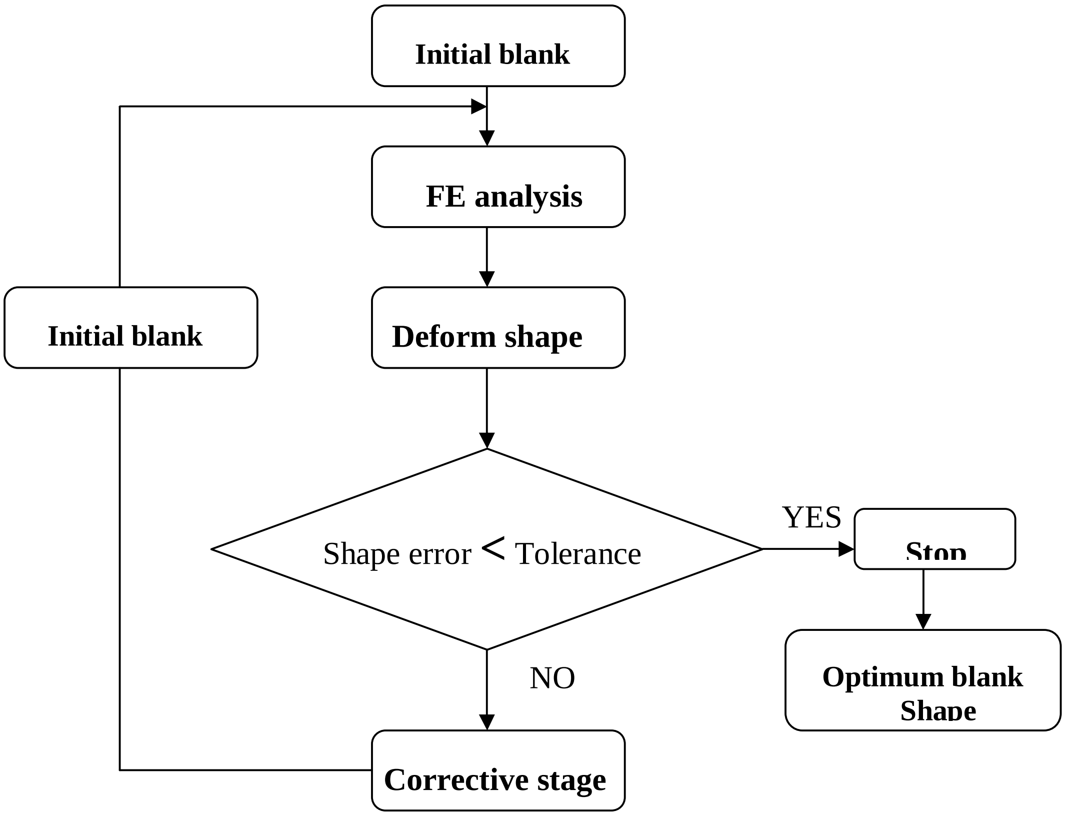
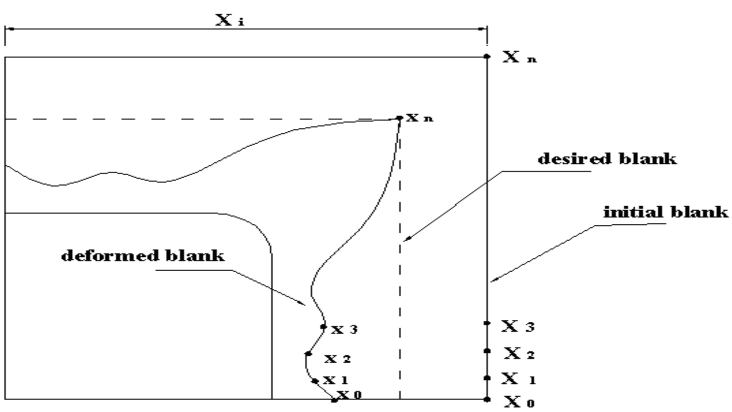


Figure (1) Optimal Blank Design Procedure.



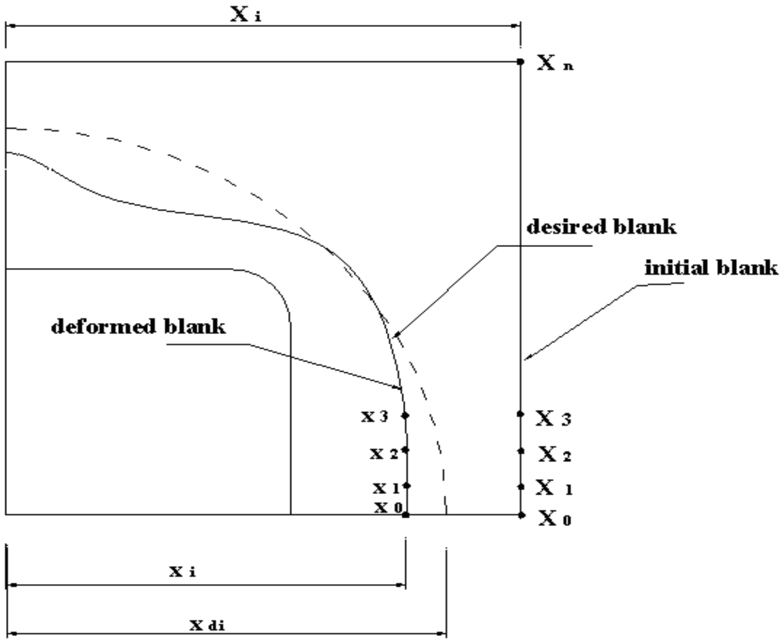


Figure (2) schematic diagram that explain the proposed algorithm

(a) Square flange (b) circular flange

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Table 1 the material properties for 1008-AISI.

Parameters	Units	Value
Young's modulus (**E**)	GPa	200
Tangent modulus (E_t)	GPa	0.5
Yield strength (σ_y)	MPa	210
Poisson's ratio (**ν**)	_	0.3
Thickness (t)	mm	0.5

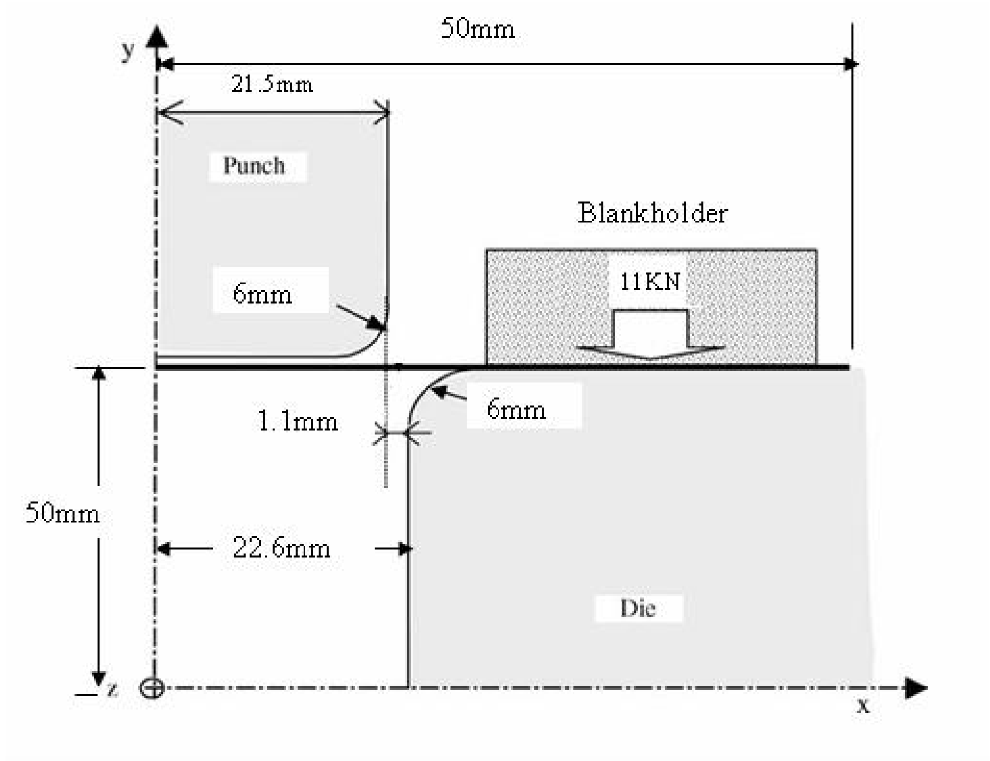
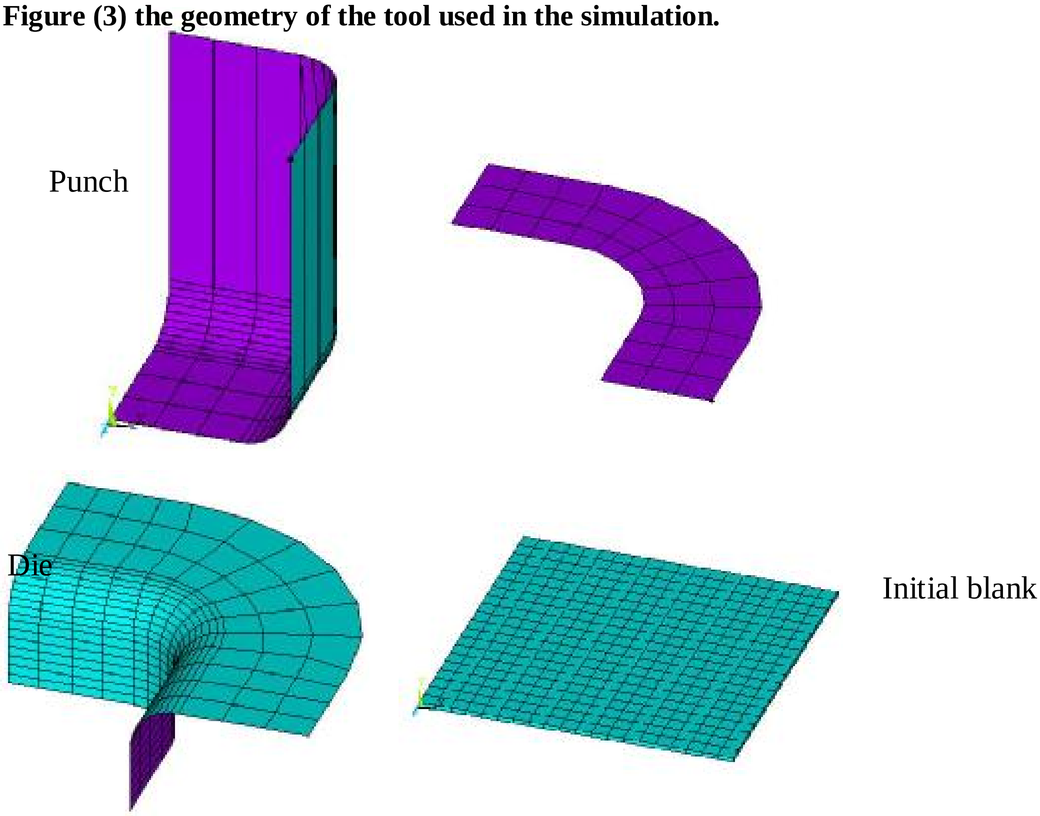


Figure (3) the geometry of the tool used in the simulation.



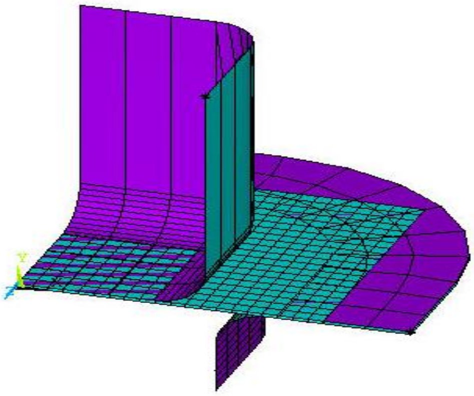
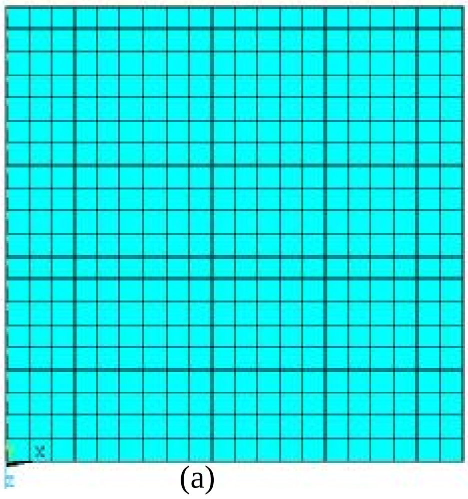
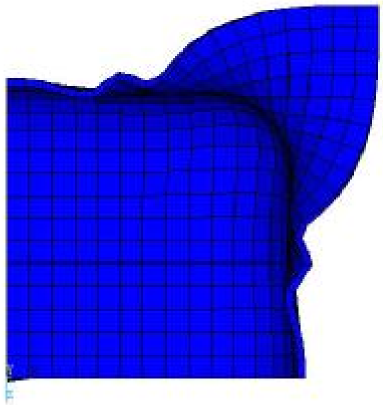


Figure (4) FE model of the tool used in the simulation.

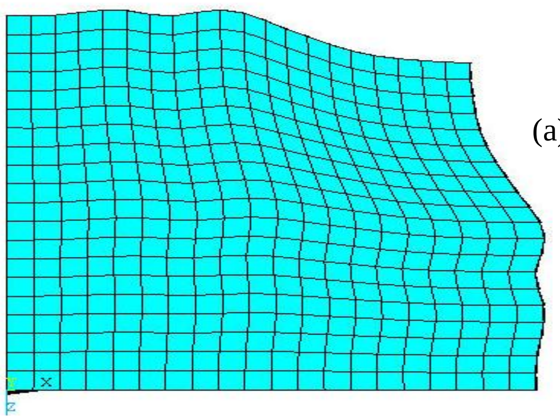


(a)

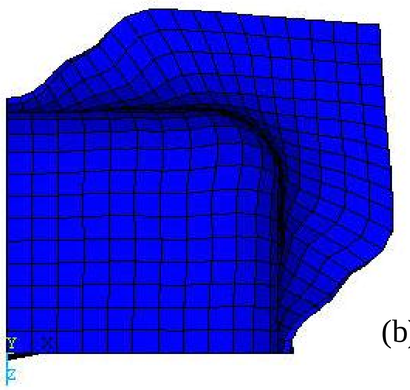


(b)

Figure (5) The result of initial square blank deformation (a) blank shape (b) deformed shape

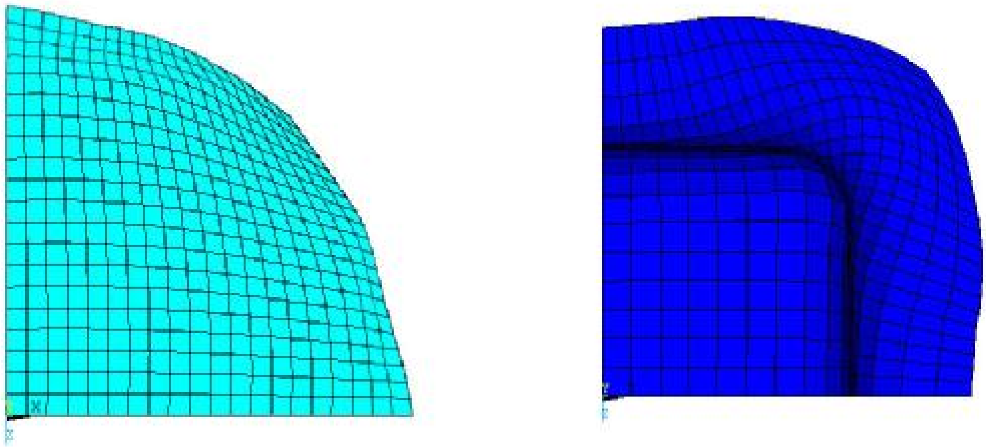


(a)



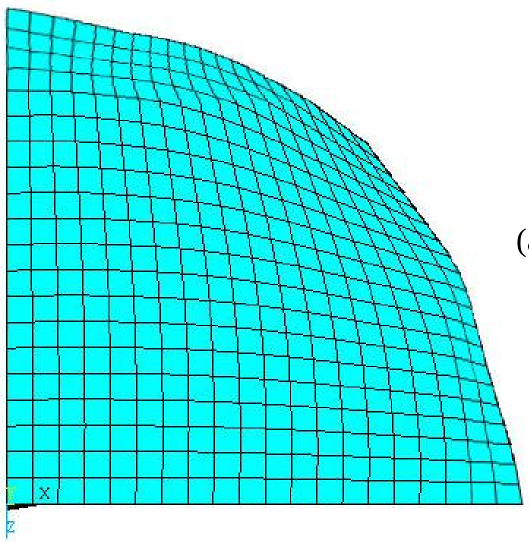
(b)

Figure (6) First blank modification (a) blank shape (b) deformed shape

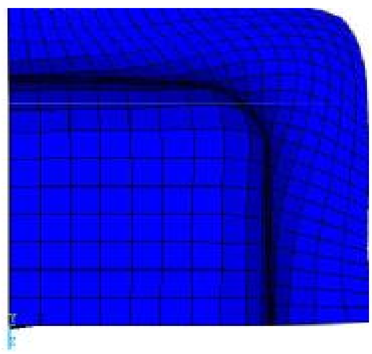


(a) (b)

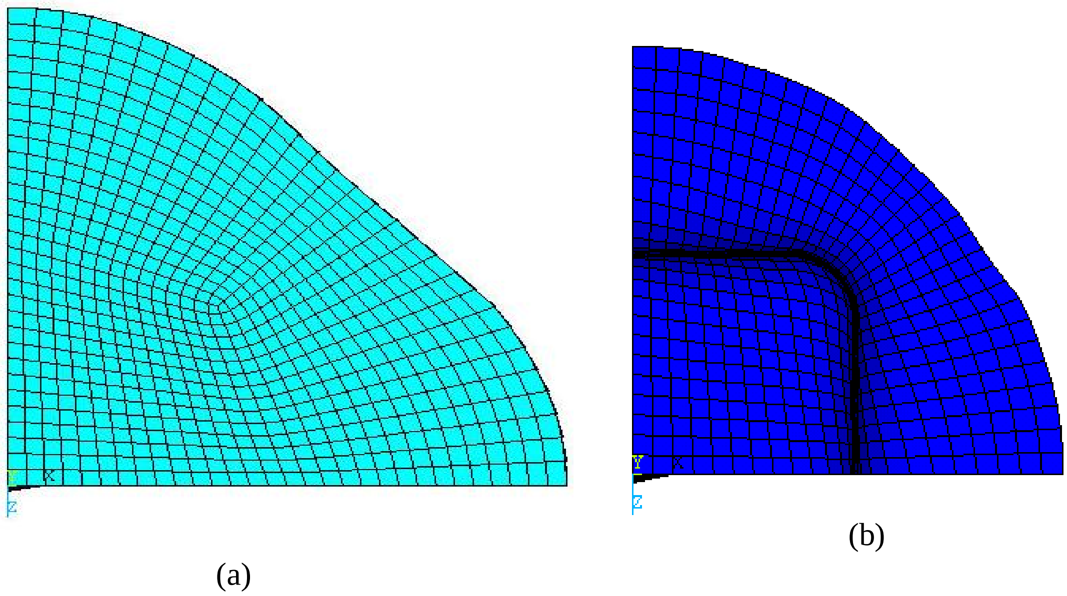
Figure (7) Second blank modification for square flange (a) blank shape (b) deformed shape



(a)



Figure(8) Third blank modification for square flange (a) blank shape (b) deformed shape



Figure(9) Second blank modification for circular flange (a) blank shape (b) deformed shape

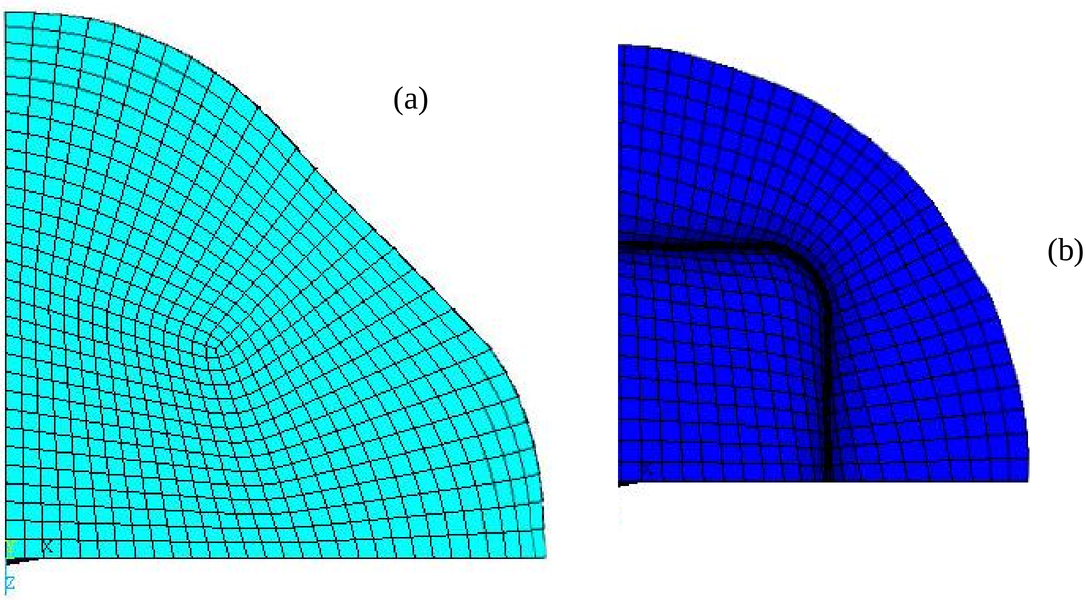


Figure (10) Third blank modification for circular flange (a) blank shape (b) deformed shape